Evaluation of Imidacloprid-Treated Traps as an Attract and Kill System for Filth Flies During Contingency Settings

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ABSTRACT

Two field trials were conducted to evaluate if filth fly trap efficacy was increased by augmentation with an insecticide application to the trap's exterior. Four Fly Terminator Pro traps (Farnam Companies, Inc, Phoenix, AZ) baited with Terminator Fly Attractant (in water) were suspended on polyvinyl chloride pipe framing at a municipal waste transfer site in Clay County, Florida. The outer surfaces of 2 traps were treated with Maxforce Fly Spot Bait (Bayer Environmental Science, Research Triangle Park, NC) (10% imidacloprid) to compare kill rates between treated and untreated traps. Kill consisted of total flies collected from inside traps and from mesh nets suspended beneath all traps, both treated and untreated. Each of 2 treated and untreated traps was rotated through 4 trap sites every 24 hrs. In order to evaluate operational utility and conservation of supplies during remote contingency operations, fly attractant remained in traps for the duration of the first trial but was changed daily during the second trial (following manufacturer's recommendations). In addition, ½ strength Terminator Fly Attractant was used during the first trial and traps were set at full strength during the second trial. Flies collected within the traps and in mesh netting were counted and identified. Three species, *Musca domestica* (L.), *Chrysomya megacephala* (F.), and *Lucilia cuprina* (Wiedemann), comprised the majority of samples in both trials. The net samples recovered more flies when the outer surface was treated with imidacloprid, however, treated traps collected fewer flies inside the trap than did untreated traps for both trials. No significant statistical advantage was found in treating Fly Terminator Pro trap exteriors with Maxforce Fly Spot Bait. However, reducing manufacturer's recommended strength of Terminator Fly Attractant showed similar results to traps set at full strength. Treating the outer surfaces may improve kill of fly species that do not enter the trap. Terminator Fly Attractant was also found to be more effective if traps were not changed daily and left to hold dead flies for longer periods.

Adult filth flies pose a health risk to humans by mechanically transmitting a wide variety of viral, bacterial, and protozoal pathogens.[1] Species in the families Muscidae, Calliphoridae, and Sarcophagidae are of particular interest to military vector control specialists because of their ability to rapidly degrade troop health through mechanical transmission of enteric pathogens such as the causal agents of dysentery and cholera.[2-4] Additionally, significant populations create a nuisance that can degrade mission readiness of deployed personnel. Baited fly traps have been used in many filth fly management programs as surveillance devices but seldom as control devices in the United States due to the offensive odor of attractants. They are used as control devices in other parts of the world but the large number of traps required to suppress adult fly populations, their associated odors, and the maintenance necessary to keep these traps operational make them impractical for fly control in the United States.[5]

Fly traps are an integral part of a filth fly management program for US military forces deployed overseas.[4] Traps with baits such as Flies Be Gone* (Combined Distributors, Inc, Jackson, NJ) that capture flies in a bag may not be optimal for success during contingency operations because the traps fill quickly and additional flies cannot be captured. Also, this trap is not designed to be reused and is typically discarded after a single use. There are reusable fly traps in the military supply system, such as the Fly Terminator Pro trap† (Farnam Companies, Inc, Phoenix, AZ), that consistently capture large numbers of flies in field trials.[6] However, this trap must also be routinely emptied and rebaited for maximum effectiveness.

An alternative to the physical capture of flies alone is the "attract and kill" insect control strategy.[7,8] This strategy

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14. ABSTRACT
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combines visual and/or chemical attractants with insecticides to lure target insects to traps and expose them to a lethal dose of insecticide before they can escape. Thus, if a trap is full and cannot physically capture additional flies, the flies that alight on the trap receive a lethal dose of insecticide, increasing the trap kill beyond what can be physically held in the trap. Some of these systems have been previously evaluated against filth flies with varying degrees of success, but additional research is needed to determine the residual efficacy and environmental degradation of the specific insecticides used in attract and kill systems.[9]

Treating a filth fly trap with an insecticide may not result in increased kill. Some plastic trap materials might be difficult to treat with residual insecticides because water-based insecticides often leave little residue on the surfaces of water-repellent plastics. Also, some commonly used pyrethroid insecticides have high excito-irritancy properties that may negate the impact of the trap's attractants,[10] lessening the trap's effectiveness. Several newer insecticides contain attractants, such as Maxforce Fly Spot Bait (Bayer Environmental Science, Research Triangle Park, NC) (active ingredient 10% imidacloprid), a sugar-baited fly insecticide. Imidacloprid is a member of a new class of insecticides (neonicotinoids), and has been shown to have exceptional potency with generally low toxicity to mammals, birds, and fish.[11]

In contingency and rapid deployment military operations, vector control personnel must reduce fly numbers quickly with a minimal amount of material and equipment. The ability to store large amounts of vector control supplies is frequently hindered by limited storage space, and manpower necessary to routinely service and maintain trapping mechanisms is often limited during contingency operations. Ideally, the effectiveness of filth fly traps could be enhanced by treating them with insecticides available to preventive medicine personnel. If this is possible, it would better serve to protect human health from filth fly-borne diseases not only during military field operations, but also in natural disaster operations and in refugee camps, both of which are increasingly involving US military assistance. The objectives of this study were to examine various application techniques using 2 fly control products to improve overall kill, including:

- Evaluate the efficacy and selectivity of fly species captured using a filth fly trap augmented with a fly-specific insecticide under field conditions.
- Determine whether the addition of insecticide to the exterior of this trap increases fly kill over traps used without insecticide.
- Compare fly capture and kill totals of traps in which Terminator Fly Attractant was not changed versus attractant changed daily.
- Determine if reducing the manufacturer's recommended strength to conserve supplies would result in satisfactory kill.

MATERIALS AND METHODS

Traps and Toxicant

The Fly Terminator Pro trap, shown in the mounting assembly in Figure 1, was selected for the field trials because of its simplistic design, durability characteristics, and demonstrated efficacy.[6] The Fly Terminator Pro is a reusable, fairly inexpensive, (one gallon) trap capable of capturing large numbers of filth flies and is baited with a potent chemical attractant (Terminator Fly Attractant). We chose Maxforce Fly Spot Bait* (10% imidacloprid) for our insecticide because it is a sugar-baited fly insecticide with quick knockdown potency that might prove useful in attract and kill systems.

Trap Design

Four Fly Terminator Pro traps were placed on an A-frame structure consisting of 2.54 cm polyvinyl chloride (PVC) pipe joined with 25.4 cm tie bands into a pyramid arrangement with the trap opening set approximately 50 cm below the apex of the pyramid and the trap bottom suspended approximately 50.8 cm above ground as shown in Figure 1. Traps were sheltered from rain with a circular 30.5 cm diameter aluminum pan. White tulle mesh netting was secured to the PVC pipes with binder clips to capture dead or moribund flies that came into contact with imidacloprid on the outer surface of the traps.

Figure 1. Fly trap and stand. Pyramid arrangement enabled use of the rain shield while keeping the trap at a useful height and minimizing ant contamination.

Field Site and Trap Positions

The field site was located at the Rosemary Hill Solid Waste Management Facility, located 16 km west of Green Cove Springs, Clay County, Florida (UTM 17 428643E; 33 18906N). Four trap sites were located around the fenced perimeter of the waste transfer building, which is on an earthen mound about 10 m above the surrounding landscape. Each trap site varied slightly with respect

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to environmental parameters, and each site was at least 20 m from the nearest trap site at the 4 corners of a square configuration as illustrated in Figure 2. Site 1 was located in partial shade closest to the waste transfer building where it was sheltered from the wind. Site 2 was located in a fairly open area between oleander bushes. Site 3 was surrounded by oleander and somewhat sheltered from the wind, while Site 4 was free of vegetation, received the greatest effects of the wind, and was not shaded.

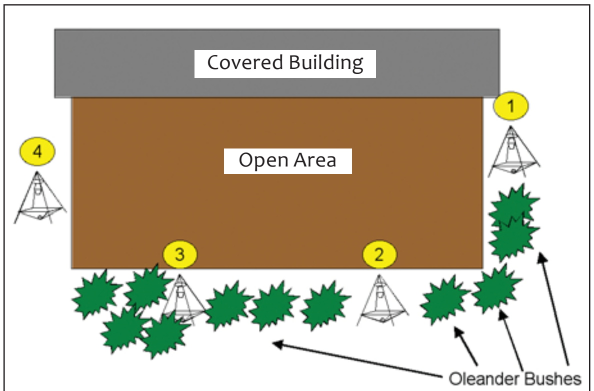

Figure 2. Plan view of fly trap positioning scheme at the Rosemary Hill Solid Waste Management Facility.

Experiment Design

Insecticide application and trapping design comparisons for Trials 1 and 2 are shown in Table 1. For Trial 1, the outer surfaces of 2 of the 4 traps were treated with Maxforce Fly Spot Bait formulated at the label rate (16 fl oz insecticide per gallon (473 mL/3.79 L) of water, prepared at the start of the trial) and applied with a one liter trigger-grip spray bottle until runoff at the beginning of each trial. The interior of each trap was also baited with Terminator Fly Attractant at ½ the manufacturer's recommended strength (0.5 fl oz/gal (14.8 mL/3.70 L) water). The bait was not refreshed during the trial. Treated and untreated traps were placed in an alternating design at sites 1-4, left at the site for 24 hours, and then rotated clockwise to the next site. This was done daily for 7 days from June 18 through June 25, 2008. Following precipitation events, the outer surfaces of 2 treated traps were re-treated with Maxforce Fly Spot Bait on June 19 and June 23 using the same mixture on both dates. Dead flies were collected from the netting daily (9 AM to 11 AM) and the contents of each trap was collected on June 25. A subset of either ¼ or ½ of the total trap catch was collected when the trap catch exceeded transfer container capacity.

The second field trial was conducted from July 29 through August 8, 2008. Traps were placed in the field and rotated as previously described. The outer surfaces of 2 traps were treated daily from July 29-31, and August 4-7 with Maxforce Fly Spot Bait, formulated and applied as described earlier, with new mixtures prepared on July 29 and August 4. Each trap was baited interiorly with Terminator Fly Attractant at full strength per manufacturer label (1 fl oz/gal (29.8 mL/3.79 L) water) and emptied and refreshed with a new mixture of attractant daily from July 29-31 and August 4-7. Dead flies were collected from the traps and netting from 9 AM to 11 AM. Temperature, relative humidity, and rainfall events were recorded daily during both trials.

Collection and Processing of Samples

For both trials, trap contents were emptied into collection pans and fluid was discarded. Netting samples were placed in vials. All trap and netting samples were returned to the Navy Entomology Center of Excellence (NECE) laboratory at the Naval Air Station Jacksonville, Florida, and stored in a freezer at -29°C until counting and specimen identification could be accomplished. A subset from throughout the entire catch (either ¼ or ½ depending on total trap catch) of flies taken from within the traps was subsequently counted and specimens were identified to species. The total number of specimens counted and identified was then multiplied by the respective number of times that original samples were divided (either by ¼ or ½). Dipterans occurring in small numbers (fewer than 25) were not identified to species. Other insect orders occurred only in very low numbers relative to dipteran species and there was no attempt to

Table 1. Experimental design and test dates of Trials 1 and 2, Rosemary Hill Solid Waste Management Facility, Clay County, Florida (17 428643E; 33 18906N).

	Trial 1 June 18-25, 2008	Trial 2 July 29-August 8, 2008
Interior trap bait (Terminator Fly Attractant) concentration in water	0.5 fl oz/gal (½ manufacturer's recommendation)	1 fl oz/gal (full manufacturer's recommendation)
Interior bait refresh	Not refreshed during entire trial	July 29, 30, 31 August 4, 5, 6, 7*
Exterior bait (Maxforce Fly Spot Bait) preparation dates (label concentration, 16 oz/gal water)	June 18	July 29 and August 4
Exterior trap surface bait treatments	June 18, 19, 23	July 29, 30, 31 August 4, 5, 6, 7*
Collections	Traps–June 25 Nets–Daily during each visit	Traps–July 30, 31, August 1 Nets–August 5, 6, 7, 8
Trap rotation	Rotated clockwise each daily visit	Rotated clockwise each daily visit

*No traps were set August 1, 2, 3.

Table 2. The proportion of the 3 primary fly species, *Musca domestica, Chrysomya megacephala,* and *Lucilia cuprina* (with total number of flies from each category in parentheses), attracted and killed by the untreated and treated Terminator® Pro traps during field Trials 1 and 2 (data not log-transformed).

Fly species (N)	Treated trap contents (n)	Untreated trap contents (n)	Net below treated trap (n)	Net below untreated trap (n)	Total (n)
Trial 1					
M. domestica	6.9% (1268)	27.5% (5024)	4.7% (852)	0.02% (4)	39.1% (7148)
C. megacephala	14.9% (2724)	37.8% (6912)	0.5% (91)	0.01% (2)	53.2% (9729)
L. cuprina	0.8% (148)	6.5% (1184)	0.4% (80)	0% (0)	7.7% (1412)
Total % (18,289)	22.6% (4,140)	71.7% (13,120)	5.6% (1,023)	0.03% (6)	
Trial 2					
M. domestica	7.1% (70)	34.1% (335)	40.1% (394)	0.9% (9)	82.2% (808)
C. megacephala	0.8% (8)	3.0% (29)	1.7% (17)	0% (0)	5.5% (54)
L. cuprina	0.8% (8)	4.6% (45)	6.9% (68)	0% (0)	12.3% (121)
Total % (983)	8.7% (86)	41.6% (409)	48.7% (479)	0.1% (9)	

identify those specimens beyond order. Voucher specimens were placed in the NECE insect collection.

Data Analysis

The effects of independent variables (treated/untreated and net/trap) on the number of flies captured were assessed using a mixed model repeated measures ANOVA with data normalized via log (n+1) transformation before analysis (Proc MIXED, SAS 9.2; SAS Institute Inc., Cary, NC). Further analyses (slice option within Proc MIXED, SAS 9.2) were conducted to determine the effects of trap device and insecticide application, and their interaction on fly kill.

RESULTS

It is estimated that nearly 20,000 flies were collected during this study. Three species, *Musca domestica* (L.) (Muscidae), *Chrysomya megacephala* (F.) (Calliphoridae), and *Lucilia cuprina* (Wiedemann) (Calliphoridae), comprised the majority of species collected from the trap units as show in Figure 3. A small number of other dipteran species, including the stable fly *Stomoxys calcitrans* (L.) and eye gnats (Chloropidae), were collected in very low numbers relative to the 3 majority species, but no attempt was made to estimate their numbers. The only nondipteran readily observed in or around the traps was the metallic green histerid beetle (*Saprinus* sp.), which was likely attracted to the fermenting combination of attractant and flies inside the trap. Analyses were conducted only on the 3 dominant fly species previously listed (*M. domestica*, *C. megacephala*, and *L. cuprina*). There was no significant effect on total flies killed due to the position of traps, other than traps located in sheltered positions which did not receive the effects of wind. Site 4 was located in an open, hillside area and received the greatest effects from wind. Flies that were dead in the netting were likely dislodged during stronger winds, therefore skewing downward the numbers collected in the netting at Site 4.

Field Trial 1

An estimated 18,289 of the dominant fly species were collected from the trap units in the first field trial; 17,260 were captured from the traps and 1,029 captured from the nets (Table 2 and Figures 3-6). *Chrysomya megacephala* (53.2%) was the most abundant fly collected, followed by *M. domestica* (39.1%) and *L. cuprina* (7.7%). There were significant differences in the fly kill rate for the untreated vs. treated trap units ($F=49.74$; $df=1,28$; $P<.0001$), with untreated trap units capturing an estimated 13,126 flies, approximately 3 times more than the imidacloprid-treated traps (n=5,163 flies). When counting trap interior fly catches, no significant difference was found in fly numbers between the treated and untreated traps ($F=3.82$, $df=1,28$; $P=.0608$). However, there were significantly more flies (n>1,000) collected in nets under the imidacloprid-treated traps than flies (n<10) collected from nets positioned under the untreated traps ($F=218.40$, $df=1,28$; $P<.0001$).

Field Trial 2

A total of 983 flies were collected from the trap units in the second field trial, shown in Figure 3 and Table 2, nearly 20 times fewer flies than were estimated collected in the first field trial. A comparable number of flies were recovered from the nets (n=488) and traps (n=495), with *M. domestica* (82.2%) and *C. megacephala* (5.5%) being the most and least abundant fly species collected, respectively. Overall, untreated and imidacloprid-treated trap units differed significantly in the fly kill rate ($F=40.44$; $df=1,44$; $P<.0001$). As with Trial 1, there was no significant difference in the number of flies recovered inside the imidacloprid-treated and untreated traps ($F=2.40$, $df=1,44$; $P=.1285$), while significant differences were found between the number of flies collected in nets under the imidacloprid-treated traps (n=479) and flies collected from nets positioned under the untreated traps (n=9) ($F=55.42$, $df=1,28$; $P<.0001$). Interestingly,

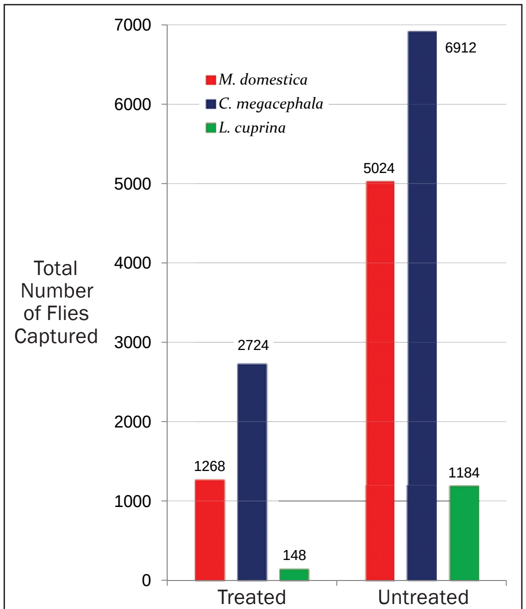

Figure 3. Trial 1, trap data for trap exteriors, untreated and treated with imidacloprid as indicated.

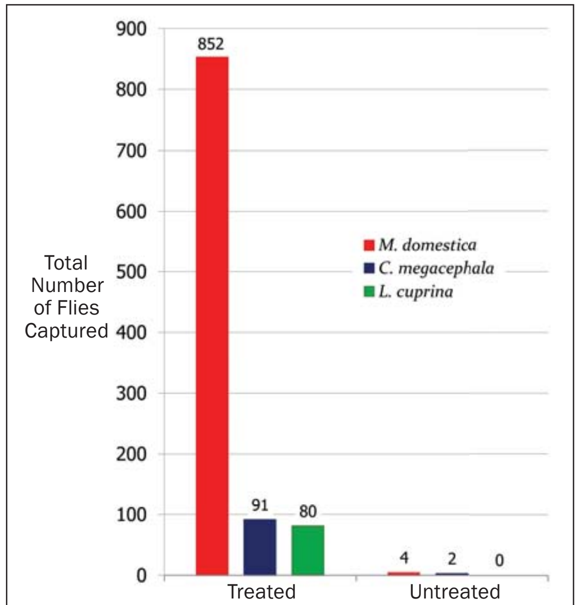

Figure 4. Trial 1, net data for trap exteriors, untreated and treated with imidacloprid as indicated.

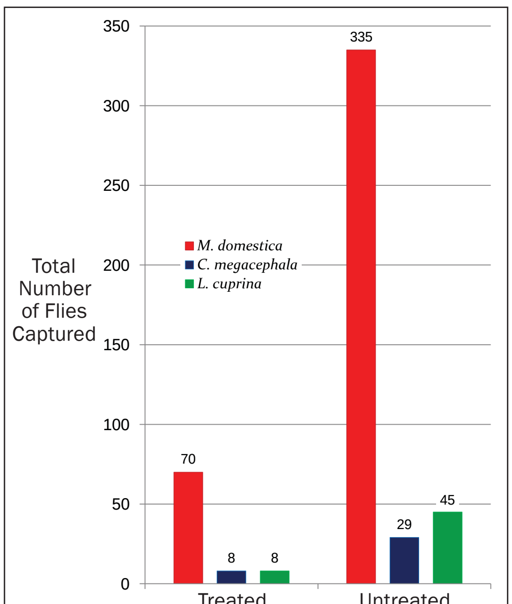

Figure 5. Trial 2, trap data for trap exteriors, untreated and treated with imidacloprid as indicated.

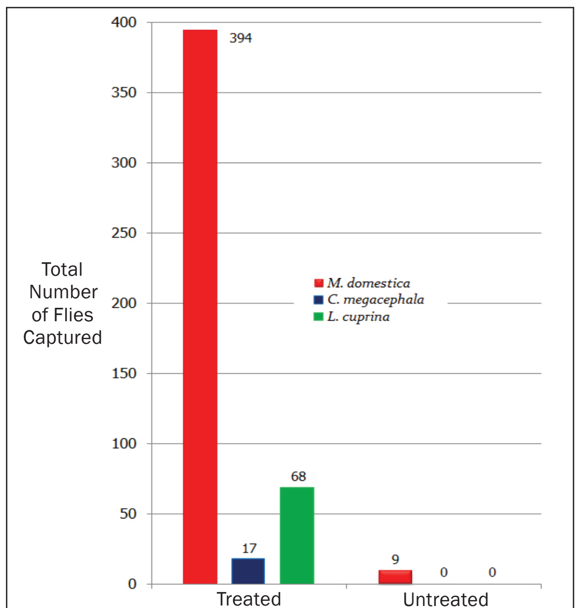

Figure 6. Trial 2, net data for trap exteriors, untreated and treated with imidacloprid as indicated.

similar fly counts were obtained from nets under imidacloprid-treated traps (n=479) and from the interior of untreated traps (n=409).

COMMENT

Depending on how often trap baits are changed, treating the exterior surface of Fly Terminator Pro traps with Maxforce Fly Spot Bait (10% imidacloprid) may not increase overall effectiveness in an attract and kill system. Although more flies were collected from nets placed under imidacloprid-treated traps than untreated traps, untreated Fly Terminator Pro traps collected more flies than the combined totals from interior of treated traps and their nets during both field trials, nullifying the significance of the number of dead flies collected from the netting. However, it is possible that a significant number of moribund flies were able to escape the netting before dying or were displaced by wind or other environmental

factors before being collected. In addition, the top portion (lid and handle) of the Fly Terminator Pro traps was not treated, and many flies were observed resting on those surfaces during the study, perhaps not receiving a lethal dose of imidacloprid.

Factors that should be evaluated before implementing fly control methodologies include desired longevity or severity of a fly problem. Environmental conditions and overall purpose will also dictate trap set-up and required maintenance regimens. For longer durations and larger fly populations, the Fly Terminator Pro traps containing attractant and dead flies become more appealing to filth flies, especially to calliphorid filth flies, the longer it is left in traps. There were fewer flies taken during the second trial (N=983) when the trap attractant was changed daily than during the first trial (N≈18,000) when attractant was left in place unchanged. There is likely a synergistic effect of attractant with dead and decaying flies to attract yet more flies to the trap. Numerous *C. megacephala* were observed flying around the inside of the trap after 2 to 3 days during the first field trial, and more *C. megacephala* were ultimately captured within the traps compared to *M. domestica*, as shown in Table 2. In contrast, when the trap contents were changed and refreshed daily during the second field trial, the majority of flies collected inside and outside of the traps were *M. domestica*. This could be attributed to seasonal influences and overall population numbers but could also be due to house fly behavior and physiology (they may land on the outside of the trap before entering and receive a lethal dose of imidacloprid before entering the trap itself). For short durations (less than 2 days), the application of spot bait to the surface of fly traps may increase the effectiveness of control efforts. Maxforce Fly Spot Bait is a wettable powder and will be washed away, especially from plastic surfaces, following precipitation events, making retreatment necessary.

Facility employees commented that fly populations were low during the the second field trial and they did not consider them a nuisance during that period. A major point of contention for these highly attractive traps is whether more flies are being attracted to a given area than would otherwise be found there; thus pre- and postsurveys of fly populations using Scudder grids and similar methods should be made in future studies. However, our assumptions before conducting these trials were that (1) adult fly populations were fairly uniform for a given location during summer months in North Florida, and (2) fly traps attract from a relatively short distance, maybe 30 m to 50 m (oral communication, J. A. Hogsette). No insecticides were applied by county or landfill personnel during these trials. Temperatures and rainfall were typical for north Florida during our trial dates, so we assume that neither weather nor human activities at Rosemary Hill Solid Waste Management Facility impacted fly populations during June, July, and August 2008.

These data indicate that there is potential for combining existing filth fly control products to create a more efficacious attract and kill system, however, expected fly population and control thresholds must first be determined for a given area where filth fly control is warranted. Although overall kill could be increased by treating the outer surface of Fly Terminator Pro traps, based on these data, treating the surfaces must occur daily, especially in areas with high humidity and precipitation. This may not be practical for some fly control programs, especially under contingency circumstances, where available manpower may be limited. Several variables should be more closely examined, such as the residual longevity of the insecticide on the outer surfaces of the traps (to include plastic and paper label on trap) in both hydric and xeric environments, and which kinds of surfaces are more prone to environmental effects such as precipitation, humidity, and dust accumulation. Trap placement (such as spacing, distance from area requiring control) and maintenance (emptying contents and treating outer surface daily vs. weekly) to create and maintain an effective barrier should also be addressed. During this study, we found that using only ½ the manufacturer's recommend strength of Terminator Fly Attractant coupled with changing traps weekly instead of daily, provided sufficient kill under resource-limited contingency settings, and resulted in greatly increased fly kill over full strength attractant-baited traps that were changed daily per manufacturer's recommendations. Future studies could include biological assays to evaluate attractant activity of different lures and currently marketed baits.

One of the goals of the Navy Entomology Center of Excellence and the Deployed War Fighter Protection Program is to develop and evaluate user friendly and economically feasible traps capable of selectively sampling filth-breeding flies. Field conditions for personnel deployed during contingency operations are often less favorable than garrison conditions, thus smaller, lighter, low maintenance traps are preferred. For example the Florida Fly-Baiter[12-16] combining visual attraction and cords treated with Maxforce Fly Spot Bait (10% imidacloprid insecticide, with attractants 0.1% muscalure ((Z)-9-tricosene) and 89.9% sugar). Additional research and testing should attempt to identify and adapt available or novel chemical attractants to augment trap efficacy and selectivity. Because few, if any, studies of this

type have been conducted to date, this study should provide additional insight into the feasibility of attract and kill filth fly systems for use in integrated fly management programs, and can be used as a stepping stone for similar studies leading to the development of better fly management systems in the future.

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